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Forum article

NEMATODES AND AGRICULTURE IN CONTINENTAL ARGENTINA. AN OVERVIEW

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Summary – In Argentina, soil nematodes constitute a diverse group of invertebrates. This widely distributed group includes more than two hundred currently valid species, among which the plant-parasitic and entomopathogenic nematodes are the most remarkable. The former includes species that cause damages to certain crops (mainly *Meloidogyne* spp, *Nacobbus aberrans*, *Ditylenchus dipsaci*, *Tylenchulus semipenetrans*, and *Xiphinema index*), the latter includes various species of the Mermithidae family, and also the genera *Steinernema* and *Heterorhabditis*. There are few full-time nematologists in the country, and they work on taxonomy, distribution, host-parasite relationships, control, and different aspects of the biology of the major species. Due to the importance of these organisms and the scarcity of information existing in Argentina about them, nematology can be considered a promising field for basic and applied research.

Résumé – ***Les nématodes et l'agriculture en Argentine. Un aperçu général*** – Les nématodes du sol représentent en Argentine un groupe très diversifié. Ayant une vaste répartition géographique, il comprend actuellement plus de deux cents espèces, celles parasitant les plantes et les insectes étant considérées comme les plus importantes. Les espèces du genre *Meloidogyne*, ainsi que *Nacobbus aberrans*, *Ditylenchus dipsaci*, *Tylenchulus semipenetrans* et *Xiphinema index* représentent un réel danger pour certaines cultures. Les parasites d'insectes comprennent plusieurs espèces de Mermithidae, ainsi que des représentants des genres *Steinernema* et *Heterorhabditis*. Les nématologistes travaillant en Argentine sont peu nombreux. Ils poursuivent des recherches très diversifiées: taxinomie, répartition, relation hôte-parasite, résistance, contrôle, biologie des principales espèces. Etant donné l'importance de ces organismes et leur connaissance encore incomplète, la nématologie peut être considérée comme ayant en Argentine un futur plein de promesses dans les domaines des recherches fondamentale et appliquée.

Key words: Agriculture, Argentina, nematology.

This article is an overview of the main features of the history of nematology in Argentina and its current status, with emphasis on its association with agriculture.

The information presented here comes from a critical analysis of the most relevant bibliographic information, from the personal experience of the authors and from their interaction with other specialists in the country.

Mainland Argentina has an area of 2 791 810 km^2 and is characterised by a great diversity of climates (Chiozza & van Domselaar, 1958) (Fig. 1) and soils (Papadakis, 1964; Moscatelli, 1990). This diversity has favoured the development of diversified agriculture, with both extensive and intensive farming systems in different regions of the country (Fig. 2). Extensive farming is used for crops such as wheat, soybean, corn, sorghum, sunflower, rice, sugar cane, barley, rye, alfalfa, peanut, rape, tobacco, grapevine, sweet potato, and potato; intensive farming produces all kinds of vegetables, and mostly tomato, garlic, pepper, beans, asparagus, and lentils. In addition, many types of fruit trees are grown in wide areas throughout the country (Gomez Riera, 1992). Aromatic and ornamental plants also are important items in the vegetal production of Argentina.

Throughout its development, Argentine agriculture has adapted to the demand of international markets. Because of this, different crops have received priority in different regions. Currently, soybean, wheat, corn, sunflower and potato are the most important species from the viewpoint of exports and domestic consumption (Cap *et al.*, 1993*a*).

Within this context of marked agricultural diversity, there exist numerous species of soil nematodes belonging to the major trophic categories (plant-parasitic, free-living, mycophagous, predators, and entomopathogenic species).

Plant-parasitic nematodes include some species that can cause serious damages to several crops, while various entomopathogenic species could be used as biological control agents against harmful insects. Recent results (Doucet & Doucet, 1996) and older data as

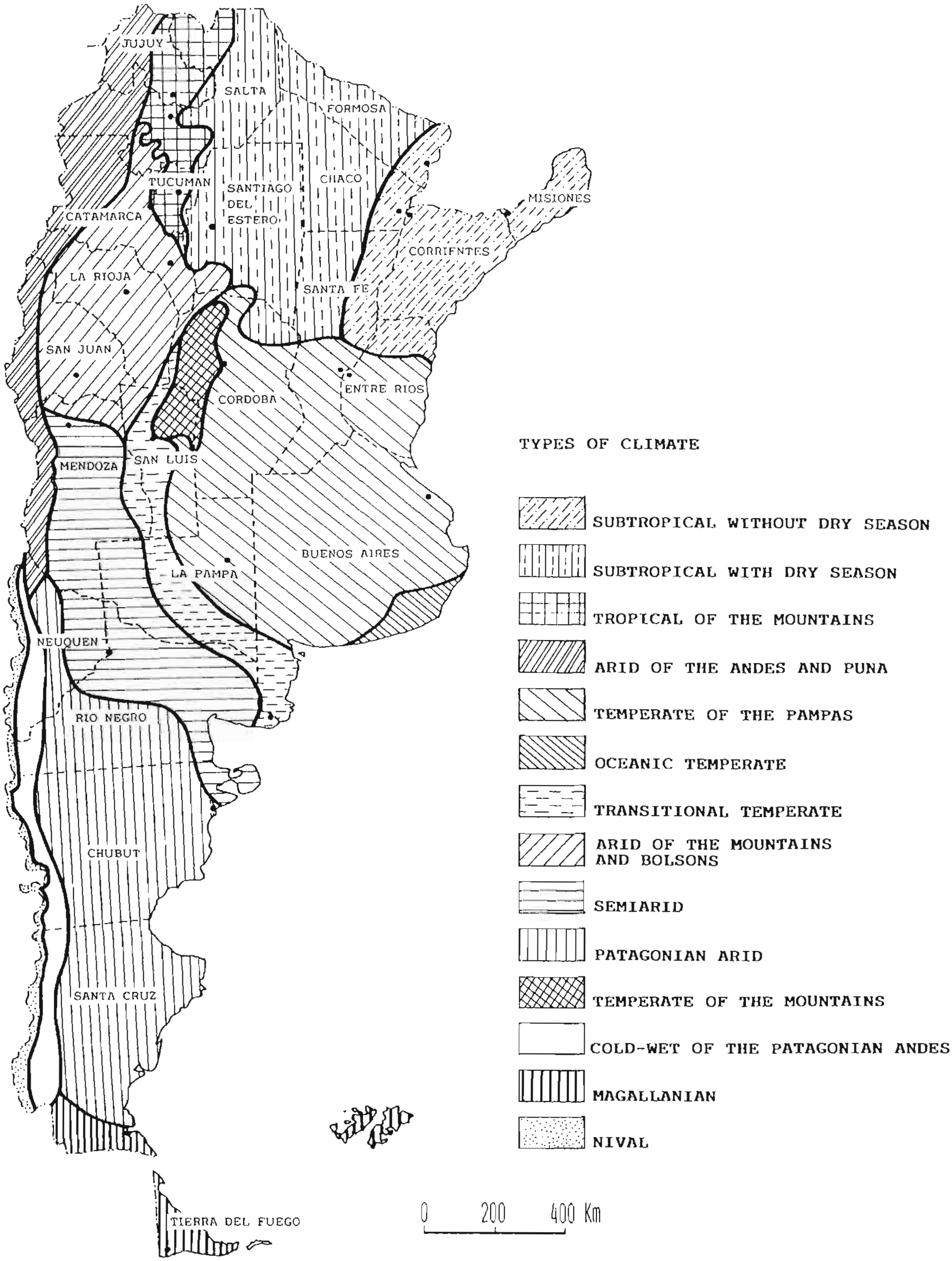

Fig. 1. *Types of climate in Argentina (adapted from Chiozza & van Domselaar, 1958).*

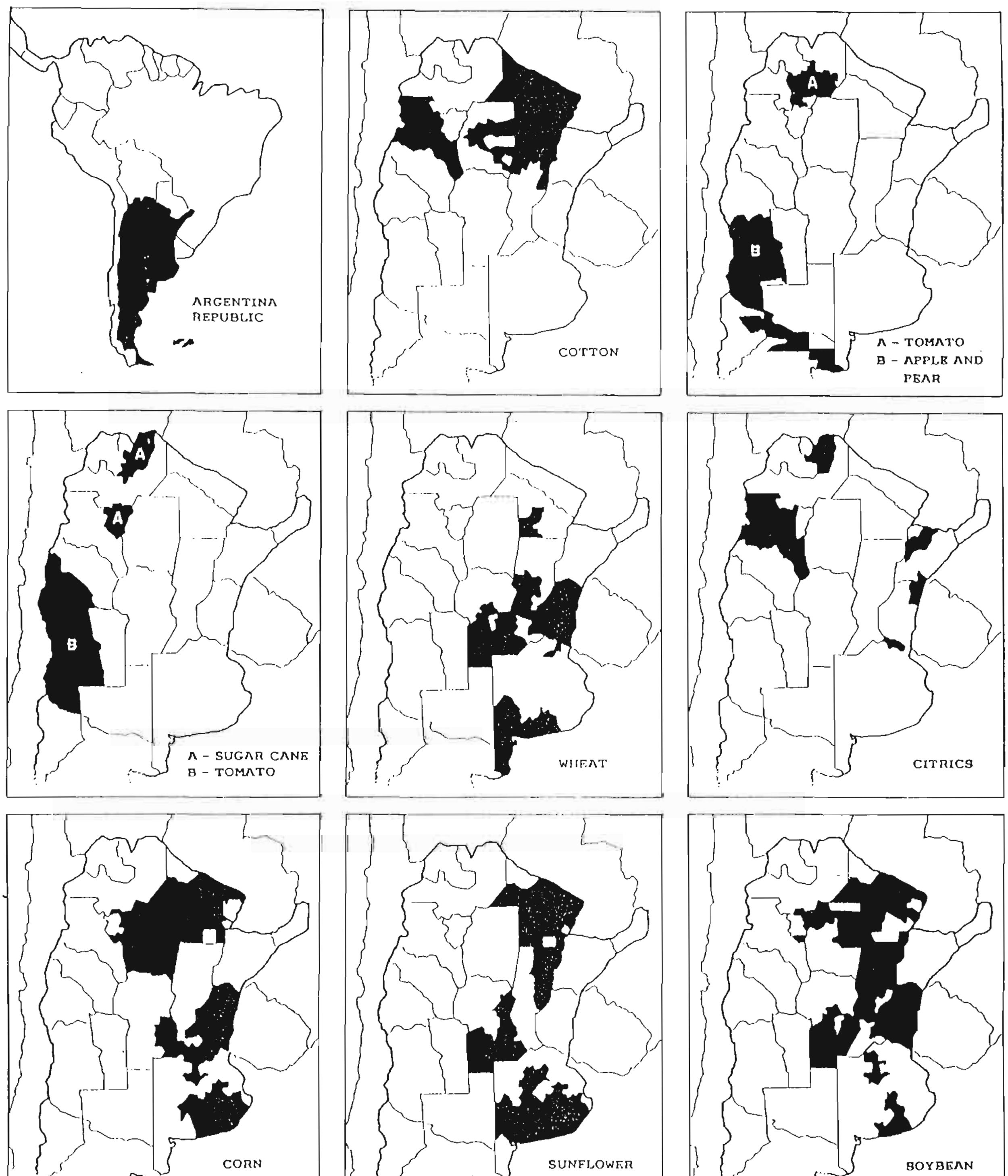

Fig. 2. *Distribution of the main crops in Argentina.*

presented in this article emphasise the great diversity of soil nematodes in Argentina.

Historical background

The first reference to soil nematodes in Argentina is related to entomopathogenic species. A German naturalist (Weyembergh, 1876) working in the National Academy of Sciences (Córdoba City) described under the name of *Gordius acridiorum* a parasite associated to one of the most important agricultural pest at that time: the locust *Schistocerca paranensis* (Burm). Later, the same investigator, with others also from Europe, reported the afore mentioned species and *G. acrydii* in locusts from Buenos Aires and Córdoba (Weyembergh, 1878, 1879; Conil, 1878, 1879; Bruner, 1898). The descriptions made at that time were not detailed, but the data published by these authors on the life-cycle and interactions of these parasites with their hosts make it obvious that these nematodes belonged to the family Mermithidae (Berg, 1898).

Only fifteen years separate the first reference to entomopathogenic species and the discovery of a plant-parasitic nematode. At the beginning of the 1890's, the Head of the Chemistry Office of the Municipality of Córdoba city – a chemist and naturalist from Germany – informed the Head of the National Department of Agriculture at Buenos Aires of the finding of "*Heterodera radicicola* de Greef" associated with grapevine, and reported some problems caused by phylloxera. He also mentioned that this pathogen had also been observed on roots of peach trees (Doering, 1891) and he added: "we have found the little animal together with the eggs in the cavities of the root-knot" (clearly a reference to the genus *Meloidogyne*).

The subsequent development of nematology in the country followed different paths for plant-parasitic, entomopathogenic, and free-living soil nematodes.

Plant-parasitic nematodes, because of their close association with economic losses to the agriculture, have received the most attention. We will now describe the activities that took place in Argentina during the development of nematological research concerning each of the three types of nematodes.

Plant-parasitic nematodes

At the beginning to this century, several articles were published on *Heterodera radicicola* (now *Meloidogyne* spp.) associated with tomato plants. Those papers are remarkable by the good information they provide on yield loss in the attacked plants, some aspects of the life cycle of the nematode and its relationships with some environmental factors, and the most convenient methods for reduction of the nematode damages (Lynch Arribálzaga, 1901; Huergo 1902, 1903).

From that time on, several species were sporadically detected in different regions, and linked to problems observed in several crops.

As time went by, some people from national organizations – *i*) Ministry of Agriculture; Instituto Nacional de Tecnología Agropecuaria (INTA): Estación Regional Experimental Balcarce (Buenos Aires province), Roque Saenz Peña (Chaco province), San Rafael (Mendoza province); *ii*) Universities (Universidad de Buenos Aires, Universidad Nacional de Córdoba, Universidad Nacional de Cuyo, Universidad Nacional de La Plata) ; provincial organizations – Dirección de Sanidad Vegetal, Ministerio de Asuntos Agrarios, Buenos Aires province; Estación Experimental Agro Industrial Obispo Colombres, Tucumán province ; and private organizations – Centro de Investigaciones Nematológicas de Corrientes – became interested in the studies of these organisms. Agriculture Engineers Burkart, Fresa and Marchionatto and Dr. R. Gutierrez were some of the people who out stood in some of those institutions for their work. Thus, "centres" of nematological activities emerged in the Buenos Aires, Mendoza and Tucumán provinces; in these last two provinces, Engineers Eduardo Vega and Miguel Costilla developed important applied works related to management of plant-parasitic nematodes associated to numerous crops. The first articles defining the status of plant-parasitic nematodes in relation to agriculture in Argentina were prepared in Buenos Aires and Mendoza (Moreno, 1964; López Cristóbal, 1965; Vega, 1971). Dr. Amalia Moreno worked in the Patología Vegetal Institute (Centro de Investigaciones Agropecuarias, INTA Castelar, Buenos Aires) where she analysed samples from different sites in the country and obtained the initial information about the distribution of different species and their relationships with their hosts.

In 1980, a new "centre" of nematological activities was created at the National University of the city of Córdoba, under the direction of the authors of this article. Both had studied nematology at "Station de Recherches sur les Nématodes" (INRA, Antibes, France). In Córdoba, they engaged in the study of soil nematodes (plant-parasitic, entomopathogenic and free-living species) and organised courses on Agricultural nematology. The first course – "Introduction to nematology" – in Argentina was presented in the Centro by the present authors in July 1980.

Almost at the same time, another nematologist, Dr. E. Chaves, was being formed at the University of Ghent, Belgium, who later joined the Unidad Integrada EEA Balcarce, Universidad Nacional de Mar del Plata, Buenos Aires.

Subsequently nematological activities started at the Universidad Nacional de Cuyo, Mendoza province (control of plant-parasitic nematodes) and at the Universidades Nacionales of Buenos Aires and La Plata (Buenos Aires province) (survey of plant-parasitic nematodes and taxonomy-biology of entomopathogenic nematodes, respectively).

More recently, other young researchers from Argentina have done postgraduate studies in Belgium and the USA, on taxonomy and the search for resistant characters.

Agricultural losses caused by plant-parasitic nematodes

In general, agricultural losses caused by nematodes are not yet known with any degree of accuracy.

According to specialised agronomists, it is possible to evaluate approximate yield reductions in some zones or average production losses for specific cultures. For example, in the western part of the country, tomato and peach trees were affected until 1970 by *Meloidogyne* spp. that reduced the yields by 20 % and 15 %, respectively. *Meloidogyne* spp. and *Xiphinema index* attacks on grapevine reduced yields by about 5 %. The use of resistant varieties and nematicides products have now reduced the losses to 2, 1, and 3 %, respectively. On garlic, *Ditylenchus dipsaci* caused damages that affected 30 % of the production between 1965-1970; the selection of non contaminated seeds and different methods of control have reduced the damages to less than 1 % of the production (Vega, pers. comm.).

Potato can be attacked by *Meloidogyne* spp. and/or *Nacobbus aberrans*, depending on the regions. The main problems occur for seed potato production. Species of *Meloidogyne* have been observed in the West (Vega *et al.*, 1986; Doucet & Ponce de León, 1996*a*) affecting 40 % of the production, the North-West (Costilla, comm. pers.), and the South-East (Chaves & Torres, 1993; Doucet & Ponce de León, 1996*a*) affecting 30 % of the production (Vega, comm. pers.).

Nacobbus aberrans has been found so far only in Tucumán and Buenos Aires areas (Costilla *et al.*, 1978; Chaves & Torres, 1993). The current legislation prohibits the use of infected tubercles for seeds; they are sold for food at lower prices.

These and other nematodes can cause a decrease of the production of several other crops. This situation has been evident for some years in horticultural crops under hot-house conditions; the economical loss has not yet been evaluated with precision.

Current list of nematode species in the country

The number of nematologists specialised in population characterisation, and identification and description of species has been and still is very low.

Unfortunately, some doubts have been expressed on past identification of some species because the variability of the characters used was not taken into account and detailed analyses of the populations were not conducted. Some identifications were probably inaccurate because those species have never been found again, although many samples were analysed. Furthermore, voucher specimens were almost never kept in local institutions or deposited in known collections.

As a consequence, it is difficult to recognise which species are of quarantine importance for the country. In some cases, the commercialisation of some agricultural products is difficult on international markets.

The list of identified species is given in the Appendix.

Active fields of research

The studies on plant-parasitic nematodes in Argentina can be divided into two main categories.

The first one is related to the acquisition of basic information: distribution, host range, some host-parasite relationships, identification and characterisation of populations of various species, and some aspects of the biology of new species. This kind of information has been obtained on the most common plant-parasitic nematodes associated with the major crops of the country (López Cristóbal, 1946, 1965; Moreno, 1958; La Red & Vega, 1968; Vega, 1971; Costilla *et al.*, 1976; Chaves, 1984; Doucet, 1986, 1989; Chaves & Torres, 1993). These activities are still being developed, and expanded to different genera and species of nematodes.

The second category is related to the management of problems caused by harmful nematodes.

From the very first projects on plant-parasitic nematodes in Argentina, the necessity of controlling nematode populations has been emphasised. The use of various chemical products has been proposed and it has been recommended to use preventive measures to avoid spreading these pathogens (Doering, 1891; Lynch Arribálzaga, 1901; Huergo, 1902, 1903). Then, several methods of crop protection were implemented.

In different cases, resistant varieties were selected (Burkart, 1934, 1937; Galmarini, 1978; Pucci & Avila, 1978; Sisler & Casaurang, 1983; March *et al.*, 1985; Costilla, 1985, 1986; Castellanos & Del Toro, 1994), crop rotation was established (Vega, 1981; Costilla, 1991), and different chemical methods were used, as explained below under the major nematodes species. Several nematicides have been tested, including DD, DBCP, methyl bromide (Gargiulo & Moyano, 1948; Vega & Gatica, 1968, 1972; Del Toro & Vega, 1982), carbofuran (Costilla, 1973), and aldicarb (Del Toro, 1988*a*). Because of their high cost, these are used generally in crops with high profitability.

Experiments have started on the use of solarization techniques as an alternative control method.

Finally, surveys have recently been initiated to delimitate areas free of specific harmful nematodes. This should make it possible to commercialise agricultural products in accordance with international regulations (Del Toro *et al*, 1994*a*).

Entomopathogenic nematodes

After the discovery that marks the beginning of Argentine nematology (Weyembergh, 1876), more than half a century passed before a second entomopathogenic nematode was detected: the mermithid *Agamermis decaudata* found parasitizing specimens of the locust *Dichroplus arrogans* Stal in Buenos Aires (Gutierrez, 1945).

At the beginnings of the 1970's, nematodes belonging to the Steinernematidae and Heterorhabditidae families, natural enemies of Coleoptera of agronomical importance (genus *Graphognatus*), were reported for the first time in the humid pampa soils (Ahmad, 1972).

The last 15 years have seen the beginning of systematic studies of entomopathogenic nematodes. Research concentrates almost exclusively on specimens of the Mermithidae, Steinernematidae and Heterorhabditidae families. Only a few studies concern nematodes of the Thelastomatidae, Rhabditidae and Diplogasteridae families (Miralles, 1982; Doucet & Doucet, 1989, 1992; Stock & Camino, 1991; Stock, 1993*c*).

In general, the nematode families which are being studied are those that include species that are being used, or may be used, as an alternative for chemical control of insect pests.

Active fields of research

Research has been developed on the following subjects:

Taxonomic studies

These include the characterisation of local populations of known species and also descriptions of new genera and species in the Mermithidae (Doucet, 1982, 1986*a*; Doucet & Poinar, 1984; Camino, 1985*a, b, c*, 1987, 1988*a*, 1990, 1991, 1993; Camino & Poinar, 1989; Camino & Stock, 1989, 1994; Stock & Camino, 1992*a,b*), Steinernematidae (Doucet, 1986*b*, 1995; Poinar *et al.*, 1988; Doucet & Doucet, 1990; Stock, 1993*b*), and Heterorhabditidae families (Stock, 1993*a*; Doucet *et al.*, 1996).

Several articles on species of the last two families have emphasised the need to consider the intraspecific variability of the characters used (Doucet & Doucet, 1986; Doucet *et al.*, 1990, 1991, 1992*a*, Doucet *et al.*, 1996).

Biological studies

The published studies described the embryonic development and life cycle of the mermithids (Camino, 1986; Camino & Reboreda, 1994) and the life cycle of heterorhabditids (Doucet & Poinar, 1985; Doucet *et al.*, 1996).

Studies on host range and aggressivity of *Heterorhabditis bacteriophora* Poinar, 1975 have recently started (Doucet *et al.*, 1992*b*; Doucet & Giayetto, 1994; Doucet *et al.*, 1996).

Ecological studies

Studies concern the geographic distribution of mermithids, steinernematids, and heterorhabditids (Doucet & Cagnolo, 1995*a*; Doucet & Bertolotti, 1995; Doucet & Doucet, 1996) and the spatial distribution patterns of Heterorhabditidae and Steinermatidae infective larvae in the soil (Doucet, 1992).

These studies continue in the Centro de Estudios Parasitológicos y Vectores (La Plata, Buenos Aires province), the Laboratorio de Nematología of the Centro de Zoología Aplicada, and the Cátedra de Parasitología, Facultad de Ciencias Exactas, Físicas y Naturales (Universidad Nacional de Córdoba).

Free-living soil nematodes

Most of the articles on free-living nematodes concern descriptions of species from various parts of the country. In particular, *Cruznema tripartitum* has been studied in relation to its possible association with a disease of garlic (Gutierrez, 1949; Avila & Pucci, 1980; Doucet & Ponce de León, 1994) and its eventual behaviour as a facultative entomopathogenic species (Doucet & Doucet, 1989; Doucet, 1994). Another interesting case is that of the free-living species *Distolabrellus veechi* Anderson, 1983 which, in specific circumstances, becomes a facultative entomopathogenic species (Doucet & Doucet, 1992).

The Argentine Society of Nematology

In 1980, at the request of INTA, the Argentine Society of Nematology was created with the objective of coordinating nematological activities in the field and promoting contacts between the specialists in the country. Its first President was the senior author of the present article and one of the most important actions of the Society was to create an awareness of the agricultural significance of soil nematodes, the damages they cause, and the possible ways to manage these parasites. To this aim, courses were organised in several institutions all over the country for teachers, technicians, researchers and other professionals involved in plant pathology. These courses proved to be one of the best ways of promoting nematology. Among those courses, one of the most remarkable was the one sponsored by ORSTOM (France) in 1986 at the Centro de Zoología Aplicada. The growing awareness of nematode problems initiated by these courses among agriculture technicians and farmers resulted in the passing by the national and provincial Ministries of Agriculture of laws intended to limit the spread of nematodes harmful to agriculture. In this manner, not only is agricultural production preserved but also the products obtained are clean and can be commercialised abroad.

Present situation

At the present, there are about ten researchers working full time on nematology. The studies that are carried out concern several subjects (survey, taxonomy, biology, management, search for resistance sources) and are principally related to plant-parasitic and entomopathogenic nematodes. Occasionally, the few specialised laboratories offer identification services for the species of importance for various crops and act as consultants for organisations related to agriculture at the national, provincial and private levels.

Major genera and species of plant-parasitic nematodes reported in Argentina and the problems they cause

From the beginning, attention has focused on harmful species in the genera *Ditylenchus*, *Meloidogyne*, *Nacobbus*, *Tylenchulus*, and *Xiphinema*.

In this context, it is necessary to mention the occurrence of the species *Ditylenchus dipsaci*, *Meloidogyne* spp., *Nacobbus aberrans*, *Tylenchulus semipenetrans* and *Xiphinema index* associated to cultivated alfalfa and garlic, potatoes and several vegetables, citrus and grapevine, respectively. Because their possible economic importance, other genera (*Pratylenchus* and *Helicotylenchus*) are also taken into account.

GENUS *DITYLENCHUS*

Two species are found in Argentina: *D. intermedius* and *D. dipsaci.*

Ditylenchus intermedius

Found in association with the tree *Platanus* sp. (Moreno & Turica, 1960), *P. acerifolia* (Brugnoni, 1980), *Citrus* sp., and grass (Moreno, 1961). The impact of this nematode on agriculture has not yet been evaluated.

Ditylenchus dipsaci

This species has created problems mostly on alfalfa and garlic. It was first recorded in the country associated with damages on alfalfa in the North-West (Anon., 1929). Several studies on *D. dipsaci* were carried out before the 1950's. The species was believed to be widely distributed in the central and northern parts of the country and to be responsible for damages of variable importance (Baez, 1925; Marchionatto *et al.*, 1926; Anon., 1929; Blanchard, 1930; Burkart, 1943; López Cristóbal, 1946; Moreno, 1964). Observations made at that time revealed the presence of plants immune to this nematode in some fields in Buenos Aires. Resistant varieties of alfalfa were then selected for the management of *D. dipsaci* (Burkart, 1934, 1937; Ragonese & Marcó, 1943; Miccio Peralta, 1956; Godeck & Favret, 1965; Godeck & Stilinovic, 1966). Since then, no more damages caused by this plant-parasitic nematode have been detected in alfalfa fields.

The crop that was the most affected by *D. dipsaci* is garlic. The climatic and edaphic conditions of the western, central-southern and south-eastern regions contributed to the fast increase of populations wherever infested seeds were used (Cucchi *et al.*, 1967; Urbieta Salvarredi *et al.*, 1971). *D. dipsaci* was first found on garlic in 1965 when it provoked a total loss of the garlic production in some areas of the province of Mendoza, the major producer of garlic in the country (Cucchi *et al.*, 1967). Simultaneously, the close association of this nematode with fungi to form a major pathologic complex was detected (Avila & Pucci, 1980). This situation was at the origin of detailed studies on the behaviour of the nematode (Urbieta Salvarredi, 1972), which resulted in the implementation of several forms of control, including thermotherapy (Del Toro & Mavrich, 1977), chemical control with synthetic nematicides (Rivera & Del Toro, 1982; Del Toro *et al*, 1988), and use of natural products (Del Toro, 1988*b*).

Today, garlic is grown on about 15 000 ha distributed in various regions, mainly the Central-West (Burba, 1992). Given the specific requirements of the Argentine regulatory legislation, special care is taken for the production of nematode-free seeds, which is enough to ensure an excellent production of garlic without nematode damages (Del Toro *et al.*, 1994*b*).

It seems that the host range of *D. dipsaci* is wide in Argentina. This nematode has been found in pastures (Burkart, 1935; Moreno & Fresa, 1969), wheat (Brugnoni, 1966), ornamental plants and weeds (Burkart, 1937; Moreno, 1956*a*; Doucet, 1992; Mareggiani & Russo, 1992), cotton (Mallo, 1961), and forest trees (Moreno & Turica, 1960; Brugnoni, 1980).

Ditylenchus spp.

Unidentified species of *Ditylenchus* have been reported in association with sugar cane in the north-western part of Argentina (Costilla *et al.*, 1976) and with cotton (Gutierrez, 1959).

GENUS *PRATYLENCHUS*

This genus is widely distributed throughout the country. So far, fourteen species have been reported in Argentina. The population densities of these species are generaly low, except in the North-West where *Pratylenchus* spp. cause damages to banana plantations (Costilla, 1973) and can affect the development and yield of corn (Costilla, 1992).

GENUS *NACOBBUS*

This genus was first found in the mountainous region of the province of Tucumán (2000 m above sea level), in soils of potato fields where it parasitises roots of cultivated and wild potatoes, *Cucurbita maxima*, *Beta* spp., and some weeds (Costilla *et al.*, 1977).

Subsequent studies showed that this nematode is widely distributed in the country (Chaves & Sisler, 1980; Chaves, 1984; Costilla, 1985; Doucet, 1989) and that it can be associated with a large number of plants, such as potatoes, vegetables and weeds (Ojeda *et al.*, 1978; Agüero *et al.*, 1984; Costilla, 1985; Doucet & Ponce de León, 1986; Ponce de León & Doucet, 1989; Doucet *et al.*, 1992; Doucet, 1992).

The analysis of morphological characters of various populations of *Nacobbus* from Argentina showed that they all belong to the species *N. aberrans* (Chaves, 1984; Costilla, 1985; Doucet, 1989; Doucet & Di Rienzo, 1991). However, preliminary observations of the behaviour of different populations in relation to different hosts revealed significant differences (Costilla, 1986). Subsequent studies based on morphometric characters (Doucet & Di Rienzo, 1991) and isoenzyme phenotypes (Doucet & Gardenal, 1992; Doucet *et al.*, 1996) revealed important differences between populations. This supports the hypothesis of a complex of forms within the species *N. aberrans* (Jatala & Golden, 1977).

The major problems caused by this species are related to the cultivation of potato (Ojeda *et al.*, 1978; Costilla, 1985).

Besides forming knots in the roots, third and fourth stage juveniles settle below the lenticels of the tuber where they reach a state of anhydrobiosis. In this state, the nematodes remain viable during storage and may be dispersed by contaminated tuber seed (Costilla, 1985). *N. aberrans* causes significant damages to crops, seriously affecting production. Because of this, the legislation requires the use of non-contaminated potato seed.

Various strategies are used against this nematode, such as the use of nematicides (Costilla & Gomez, 1981), the assessment of resistance of different cultivars (Sisler & Casaurang, 1983), and crop rotation (Costilla, 1991).

A search for sources of resistance in *Lycopersicon* has recently been launched (Cap *et al.*, 1993*b*).

GENUS *HELICOTYLENCHUS*

This genus is widely distributed in Argentina. It includes several populations, most of which have not been identified at the species level.

The most important species identified so far – *H. multicinctus* – was found in the North-West on roots of banana trees, where it produces characteristic lesions (Costilla *et al.*, 1979).

GLOBODERA ROSTOCHIENSIS

This nematode was first reported in Argentina in the soil of a garlic field in the western part of the country (Moreno, 1956*b*). Later, it was mentioned in the Andes, Province of Jujuy, parasitizing roots of wild potatoes (Brücher, 1960, 1961). Years later, it was reported in the soil of a potato field in another mountainous region in the West (Virsoo, 1967).

Since then, the numerous analyses carried out by different laboratories on soil samples and tubers from many different regions all had negative results (Chaves, 1993). Work on cyst nematodes from Argentina suggests that this species is not present in the country (Chaves, 1987, 1993; Chaves & Torres, 1993).

Because of the first four bibliographic references, some countries hinder exports of certain agricultural products and demand regulatory certifications. However, there are no objective proofs of the occurrence of *G. rostochiensis* in the country.

For the last two years, surveys have been in progress in order to demonstrate that specific areas of garlic, potato and onion production are free of *G. rostochiensis* (Del Toro *et al.*, 1994*a*).

GENUS *MELOIDOGYNE*

As mentioned above, the discovery of a species of this genus marks the beginning of the study of plant-parasitic nematodes in Argentina. Since then, species of the genus *Meloidogyne* have been found on roots of various plants: vegetables, potatoes, tobacco, soybean, cotton, ornamental plants, fruit trees, forest trees, and weeds.

Reviews of the existing information on the genus have recently been published (Doucet & Pinochet, 1992; Doucet, 1993; Doucet & Ponce de León, 1996*b*).

Nine species have been detected: *M. acrita*, *M. arenaria* (race 2), *M. chitwoodi*, *M. cruciani*, *M. decalineata*, *M. hapla*, *M. incognita* (races 1, 2, and 3), *M. javanica*, *M. ottersoni*, in addition to some populations reported as *Meloidogyne* spp. whose specific identity is unknown.

One hundred plant species (belonging to 33 families) can be parasitised by the eight species of *Meloidogyne*. *M. incognita* and *M. arenaria* are the most frequently found species, and they parasitise 56 % and 27 % of plants, respectively (Doucet, 1993). Cultivated as well as wild plants (native and introduced) can be attacked by these nematodes, but mostly weeds and vegetables.

Although the genus is widely distributed and has a very wide range of hosts, populations, and damages, appear to be limited to some relatively small areas.

Major damages are observed in vegetables (particularly tomato and pepper), potato, grapevine, and soybeans. They are managed by conventional nematicides controlling soil populations, crop rotations, and resistant varieties.

Potatoes present a particular challenge because the nematodes parasitise the tubers and can thus be transported to new sites when contaminated tubers are used for seed. Because of the high reproductive potential of these nematodes and their polyphagous behaviour, planting pieces of infested tubers will create a serious problem to soils and future crops (Chaves & Torres, 1993; Doucet & Ponce de León, 1996*a*). The legislation prohibits the use of infested potato seed, which helps preventing the dispersal of these nematodes.

TYLENCHULUS SEMIPENETRANS

Tylenchulus semipenetrans was found for the first time in the North-East of the country on roots of citrus trees (Fresa, 1943). Later, it was found associated with different varieties of citrus in several regions, mainly the North-West and the North-East (Marchionatto, 1945, 1946, 1947; Schultz, 1945; Gutierrez, 1947; López Cristóbal, 1965; Moreno, 1969). In all cases, the nematode was linked to a decrease in citrus yields. The distribution of this nematode is very limited. The problems it causes are managed by resistant graft (Doucet & Ponce de León, 1992; Costilla, pers. comm.).

FAMILY LONGIDORIDAE

So far, three genera have been detected: *Xiphinema*, *Xiphidorus*, and *Paraxiphidorus*. The first genus has a low diversity; only seven species are present in Argentina. On the contrary, all the known species of the second genus are represented in the country to the exception of *X. uruguayensis*. The third genus includes only the type species (Coomans & Chaves, 1995).

Regarding the relative importance of these genera, it is necessary to mention the following species:

Xiphinema index

Xiphinema index was first found in the West on grapevines infested with grape-vine fan leaf virus and grape yellow mosaic virus (Feldman & Pontis, 1963, 1964). This species is widely distributed in the wine-growing region of the Province of Mendoza (La Red & Vega, 1968; Cucchi *et al.*, 1971; Vega, 1971, 1978). It was also found in grapevine plantations in the central part of the country – without any virus-related diseases – and on citrus roots in the North-East (Luc & Doucet, 1990).

The damages caused by this species on grapevines were controlled by nematicides (La Red & Vega, 1970).

Xiphinema americanum sensu lato

X. americanum sensu lato is the species of the genus *Xiphinema* the most frequently found in the country. It is associated with a great variety of crops (tobacco, citrus, sugar cane, grapevine, barley, tomato, several fruit trees) as well as wild plants. It is widely distributed (Luc & Doucet, 1990). It is not known whether the populations of this species can transmit pathogenic viruses.

Main genera and species of entomopathogenic nematodes recorded in Argentina

FAMILY MERMITHIDAE

From the results of the studies made so far, it can be said that the Mermithidae family is characterised by a great generic and specific diversity in the country. Fifteen genera have been observed: three terrestrial and twelve aquatic genera. Two of them were found for the first time in Argentina: *Ditremamermis* Camino & Poinar, 1989 and *Divisispiculimermis* Doucet, 1986. The best represented genera are *Mesomermis* and *Gastromermis*, both including mostly species parasites of simulids.

So far, *Strelkovimermis spiculatus* – a parasite of mosquitoes – is the only species studied in the laboratory to obtain information on its physiology and modalities of infection (Camino, 1988*b*,*c* ; Camino & García, 1991, 1992).

Among terrestrial mermithids, the most remarkable are the genus *Hexamermis* including the largest number of species and the species *Agamermis decaudata* because of its large geographic distribution (Camino *et al.*, 1986; Doucet & Cagnolo, 1995*b*).

FAMILY HETERORHABDITIDAE

The genus *Heterorhabditis* is represented by the species *H. argentiniensis* and *H. bacteriophora*. Only one population of the first species has been observed (Stock, 1993*a*) whereas several populations of the second species have been found in various locations in the country (Doucet & Bertolotti, 1995; 1996).

In the laboratory, two *H. bacteriophora* populations from Córdoba have shown promises as efficient biological control agents against Lepidoptera and Coleoptera (Scherma & Rodriguez Mosquera, 1989; Doucet & Giayetto, 1994).

FAMILY STEINERNEMATIDAE

So far, six species of the genus *Steinernema* are known in Argentina. *S. feltiae* was found in the Santa Fe province (Stock, 1993*b*), *S. scapterici* in Buenos Aires (Stock, 1992), and *S. carpocapsae, S. glaseri, S. rara,* and *S. ritteri* were found in Córdoba.

Except for *S. glaseri*, which was observed in mountain forest soil, the *Steinernema* species were found in cultivated soils.

Two species, *S. carpocapsae* and *S. rara* could become good control agents of harmful Homoptera, Lepidoptera and Coleoptera (Doucet, 1981).

Conclusion

Our knowledge of the soil nematodes that are present in the country is still insufficient. Because of the great diversity of conditions, it is reasonable to suppose that there is a marked diversity of species. It may be necessary to confirm the previous identification of some of the species by means of detailed studies.

Concerning the species of plant-parasitic nematodes, it remains necessary to assess more accurately the impact they have on the crops they attack. Because of a lack of symptoms, the attack of these pathogens sometimes goes unnoticed or is ascribed to other agents.

In those cases in which the harmful association nematode-plant is confirmed, it is essential to obtain more information on the biology of these species. The knowledge of the type of behaviour and the characterisation of the different populations of particular species (particularly *Meloidogyne* spp. and *Nacobbus aberrans*) will allow the development of strategies aimed at ensuring plant production and preserving good soil conditions.

In Argentina, research remains aimed at the study of the major species of plant-parasitic nematodes associated with potato and soybean and with vegetables in general, and toward the development of different types of control measures.

In relation to entomopathogenic nematodes, the objective of the investigations is to increase our knowledge on the species present, on the aggressivity of different populations, and to evaluate their potentials as biological control agents.

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Appendix

List of soil nematodes reported in continental Argentina (doubtful records are marked with an asterisk [*]).

Class Adenophorea
Subclass Enoplia
Order Enoplida

Family Tripylidae

Trischistoma monohysteroides Altherr, 1963
Trischistoma monohystera (de Man, 1880) Schuurmans Stekhoven, 1951
Tripyla sp.
Tobrilus macrospiculum Altherr, 1963
Tobrilus papillicaudatus Altherr, 1963
Tobrilus setosus Altherr, 1963
Tobrilus sp.

Family Ironidae

Ironus filiformis Altherr, 1963

Order Mononchida

Family Cobbonchidae

Cobbonchus regulus Altherr, 1963

Family Mononchidae

Clarkus papillatus (Bastian, 1865) Jairajpuri, 1970
Coomansus gerlachei (de Man, 1904) Jairajpuri & Khan, 1977
Mononchus aquaticus Coetzee, 1968
Mononchus bellus Andrássy, 1985
Mononchus sp.
Prionchulus muscorum (Dujardin, 1845) Wu & Hoeppli, 1929

Family Mylonchulidae

Mylonchulus brachyuris (Bütschli, 1873) Altherr, 1953
Mylonchulus hawaiiensis (Cassidy, 1931) Andrássy, 1958
Mylonchulus minor (Cobb, 1893) Andrássy, 1958
Mylonchulus parabrachyurus (Thorne, 1924) Andrássy, 1958
Mylonchulus sigmaturus (Cobb, 1917) Altherr, 1953
Mylonchulus sp.
Sporonchulus ibitiensis (Carvalho, 1951) Andrássy, 1958

Family Iotonchidae

Iotonchus arenicola Altherr, 1963
Iotonchus geminis Heyns & Lagerwey, 1965
Iotonchus monhystera (Cobb, 1917) Jairajpuri, 1970

Order Mermithida

Family Mermithidae

Agamermis decaudata Cobb, Steiner & Christie, 1926
Amphimermis bonariensis Miralles & Camino, 1983
Bathymermis simuliae Camino, 1993
Ditremamermis simuliae Camino & Poinar, 1989
Divisispiculimermis mirus Doucet, 1986
Gastromermis cordobensis Camino, 1991
Gastromermis doloresi Camino, 1993
Gastromermis fidelis Doucet, 1982
Gastromermis kolleonis Doucet & Poinar, 1984
Gastromermis vaginiferous Camino, 1985
Hexamermis cochlearius Stock & Camino, 1992
Hexamermis hortensis Camino & Stock, 1989
Hexamermis macrostoma Camino & Stock, 1994
Hexamermis ovistriata Stock & Camino, 1992
Hydromermis sp.
Hydromermis doloresi Camino, 1993
Isomermis sp.
Isomermis sierrensis Camino, 1994
Limnomermis bonariensis Camino, 1989
Limnomermis sp.
Mermis sp.
Mesomermis crassivaginae Camino, 1985
Mesomermis dissimilis Camino, 1985
Mesomermis delponteiana Camino, 1990
Mesomermis nortensis Camino, 1991
Mesomermis ochrae Camino, 1985
Mesomermis subandina Camino, 1985
Mesomermis sp.
Octomyomermis albicans Camino, 1985
Octomyomermis arecoensis Camino, 1991
Octomyomermis bonariensis Camino, 1988
Octomyomermis longispiculae Camino, 1992
Pseudomermis sp.
Strelkovimermis spiculatus Poinar & Camino, 1986
Strelkovimermis sp.

Order Dorylaimida

Family Actinolaimidae

Actinolaimus sp.

Family Aporcelaimidae Heyns, 1965

Aporcelaimellus obscurus (Thorne & Swanger, 1936) Heyns, 1965

Aporcelaimellus sp.
Aporcelaimus sp.

Family Belondiridae

Dorylaimellus monticolus Clark, 1963
Dorylaimellus virginianus Cobb, 1913

Family Charcharolaimidae

Carcharolaimus formosus Lordello, 1957
Carcharolaimus rotundicauda (de Man, 1880) Thorne, 1939
Carcharolaimus sp.

Family Leptonchidae

Leptonchus granulosus Cobb, 1920
Leptonchus sp.
Tylencholaimellus montanus Thorne, 1939

Family Longidoridae

Paraxiphidorus michelluci Coomans & Chaves, 1995
Paraxiphidorus sp.
Xiphidorus achalae Luc & Doucet, 1984
Xiphidorus balcarceanus Chaves & Coomans, 1984
Xiphidorus tucumanensis Chaves & Coomans, 1984
Xiphidorus saladillensis Chaves & Coomans, 1984
Xiphidorus yepesara Monteiro, 1976
Xiphidorus sp.
Xiphinema americanum Cobb, 1913
Xiphinema diversicaudatum (Micoletzky, 1927) Thorne, 1939
Xiphinema index Thorne & Allen, 1950
Xiphinema krugi Lordello, 1955
Xiphinema setariae Luc, 1958
Xiphinema rivesi Dalmasso, 1969
Xiphinema surinamense Loof & Maas, 1972
Xiphinema sp.

Family Mydonomidae

Dorylaimoides elongatus Husain & Khan, 1968

Family Nordiidae

Pungentus monhystera Thorne & Swanger, 1936

Family Dorylaimidae

Dorylaimus sp.
Mesodorylaimus aberrans Loof, 1969
Mesodorylaimus adalberti Andrássy, 1963
Mesodorylaimus argentinus Altherr, 1963
Mesodorylaimus derni Loof, 1969
Mesodorylaimus meridianus Andrássy, 1963
Mesodorylaimus pseudobastiani Loof, 1969
Mesodorylaimus puellae Andrássy, 1963
Mesodorylaimus szekessyi Andrássy, 1960
Mesodorylaimus sp.

Family Nygolaimidae

Nygolaimus sp.

Family Qudsianematidae

Eudorylaimus monohystera (de Man, 1880) Andrássy, 1959
Eudorylaimus obtusicaudatus (Bastian, 1865) Andrássy, 1959
Eudorylaimus profestus Andrássy, 1963
Eudorylaimus quadramphidius Andrássy, 1963
Eudorylaimus sp.
Labronema sp.

Order Triplonchida

Family Diphterophoridae

Diphterophora communis de Man, 1880
Diphterophora sp.

Family Trichodoridae

Paratrichodorus minor (Colbran, 1956) Siddiqi, 1974
Paratrichodorus sp.
Trichodorus obscurus Allen, 1957
Trichodorus sp.

Subclass Chromadoria
Order Araeolaimida

Family Plectidae

Anaplectus sp.
Plectus (Plectoides) patagonicus de Man, 1904
Plectus sp.

Order Chromadorida

Family Cyatholaimidae

Odontolaimus aquaticus W. Schneider, 1937

Order Monhysterida

Family Monhysteridae

Monhystera lepidura Andrássy, 1963
Monhystera sp.

Class Secernentea
Subclass Rhabditida
Order Rhabditida

Family Cephalobidae

Acrobeles sp.
Acrobeles emmatus Shahina & De Ley, 1997
Acrobeloides sp.
Cephalobus sp.
Cervidellus sp.
Eucephalobus sp.
Nothacrobeles lunensis Shahina & De Ley, 1997
Zeldia sp.

Family Rhabditidae

Cephaloboides sp.
Cruznema tripartitum (Linstow, 1906) Zullini, 1982
Cruznema sp.
Distolabrellus veechi Anderson, 1983
Oxycerca brevispina (de Man, 1895) Andrássy, 1983
Pelliodiits pellio (Schneider, 1866) Timm, 1960

Rhabditis spp.

Family Heterorhabditidae

Heterorhabditis argentiniensis Stock, 1993
Heterorhabditis bacteriophora Poinar, 1975
Heterorhabditis sp.

Family Steinernematidae

Steinernema carpocapsae (Weiser, 1955) Poinar, 1990
Steinernema feltiae (Filipjev, 1934) Poinar, 1990
Steinernema glaseri (Steiner, 1929) Poinar, 1990
Steinernema rarum (Doucet, 1986) Poinar, 1990
Steinernema ritteri Doucet & Doucet, 1990
Steinernema scapterisci Nguyen & Smart, 1991
Steinernema sp.

Family Panagrolaimidae

Panagrolaimus sp.

Order Ascaridida

Family Thelastomatidae

Leidynema appendiculatum (Leidy, 1890) Chitwood, 1932
Pseudonymus sp.
Thelastoma dessetae Adamson, 1985

Order Diplogasterida

Family Diplogastridae

Micoletzkya vidalae Stock, 1993

Order Aphelenchida

Family Aphelenchidae

Aphelenchus avenae Bastian, 1865
Aphelenchus sp.

Family Aphelenchoididae

Aphelenchoides bicaudatus (Imamura, 1931) Filipjev & Schuurmans Stekhoven, 1941
Aphelenchoides blastophthorus Franklin, 1952
Aphelenchoides fragariae (Ritzema Bos, 1890) Christie, 1932
Aphelenchoides parietinus (Bastian, 1865) Steiner, 1932
Aphelenchoides ritzemabosi (Schwartz, 1911) Steiner, 1932
Aphelenchoides sp.
Laimaphelenchus cocuccii Doucet, 1992
Laimaphelenchus sp.
Seinura sp.

Family Ektaphelenchidae

Ektaphelenchus tenuidens (Thorne, 1935) Rühm, 1956

Order Tylenchida

Family Tylenchidae

Atylenchus sp.
Atylenchus decalineatus Cobb, 1913
Boleodorus sp.
Cephalenchus sp.
Coslenchus sp.
Filenchus sp.
Lelenchus sp.
Psilenchus bahiablancae Doucet, 1996
Psilenchus hilarus Siddiqi, 1963
Psilenchus pratensis Doucet, 1996
Psilenchus sp.
Tetylenchus sp.
Tylenchus sp.
Tylenchus davanei Bastian, 1985
Tylenchus filiformis Micoletzky, 1922

Family Anguinidae

Anguina agrostis (Steinbuch, 1799) Filipjev, 1936
Anguina sp.
Ditylenchus dipsaci (Kühn, 1857) Filipjev, 1936
Ditylenchus intermedius (de Man, 1880) Filipjev, 1936
Ditylenchus sp.
Orrina phyllobia (Thorne, 1934) Thorne, 1961

Family Belonolaimidae

Belonolaimus gracilis Steiner, 1949 *
Belonolaimus brevicaudatus (Doucet, 1983) Fortuner & Luc, 1987
Tetylenchus sp.
Triversus festonatus (Doucet, 1985) Fortuner & Luc, 1987
Tylenchorhynchus acti Hooper, 1959
Tylenchorhynchus annulatus (Cassidy, 1930) Golden, 1971
Tylenchorhynchus capitatus Allen, 1955
Tylenchorhynchus cylindricus Cobb, 1913
Tylenchorhynchus dubius (Bütschli, 1837) Filipjev, 1936
Tylenchorhynchus sp.

Family Dolichodoridae

Dolichodorus aquaticus Doucet, 1985
Dolichodorus heterocephalus Cobb, 1914 *
Dolichodorus longicaudatus Doucet, 1981
Neodolichodorus leiocephalus Doucet, 1981

Family Pratylenchidae

Pratylenchus agilis Thorne & Malek, 1968
Pratylenchus brachyurus (Godfrey, 1929) Filipjev & Schuurmans Stekhoven, 1941
Pratylenchus delattrei Luc, 1958
Pratylenchus goodeyi Oostenbrink, 1953
Pratylenchus hexincisus Taylor & Jenkins, 1957
Pratylenchus microstylus Bajaj & Bahatti, 1984
Pratylenchus neglectus (Rensch, 1924) Filipjev & Schuurmans Stekhoven, 1941
Pratylenchus penetrans (Cobb, 1917) Filipjev & Schuurmans Stekhoven, 1941
Pratylenchus pratensis Meyl, 1954
Pratylenchus pseudopratensis Seinhorst, 1968
Pratylenchus scribneri Steiner, *in* Sherbakoff & Stanley, 1943
Pratylenchus thornei Sher & Allen, 1953
Pratylenchus vulnus Allen & Jensen, 1951
Pratylenchus zeae Graham, 1951

Pratylenchus sp.
Radopholus similis (Cobb, 1893) Thorne, 1949
Nacobbus aberrans (Thorne, 1935) Thorne & Allen, 1944

Family Hoplolaimidae

Aorolaimus longistylus (Doucet, 1980) Fortuner, 1987
Aorolaimus perscitus (Doucet, 1980) Fortuner, 1987
Aorolaimus conicori (Doucet, 1984) Fortuner, 1987
Aorolaimus brevicaudatus (Doucet, 1984) Fortuner, 1987
Aorolaimus triticeus (Doucet, 1984) Fortuner, 1987
Aorolaimus sp.
Helicotylenchus nannus Steiner, 1945
Helicotylenchus digonicus Perry, *in* Perry, Darling & Thorne, 1959
Helicotylenchus multicinctus (Cobb, 1893) Golden, 1956
Helicotylenchus pseudorobustus (Steiner, 1914) Golden, 1956
Helicotylenchus sp.
Hoplolaimus galeatus (Cobb, 1913) Thorne, 1935
Hoplolaimus sp.
Rotylenchus buxophilus Golden, 1956
Rotylenchus goodeyi Loof & Oostenbrink, 1958
Rotylenchus robustus (de Man, 1876) Filipjev, 1936
Rotylenchus uniformis (Thorne, 1949) Loof & Oostenbrink, 1958
Rotylenchus sp.

Family Heteroderidae

Cactodera amaranthi (Stoyanov, 1972) Krall' & Krall', 1978
Cactodera sp.
Globodera rostochiensis (Wollenweber, 1923) Behrens, 1975 *
Globodera tabacum tabacum (Lownsberry & Lownsberry, 1954) Behrens, 1975
Globodera sp.
Heterodera schachtii Schmidt, 1871 *
Heterodera galeopsidis Goffart, 1936
Heterodera spp.
Meloidogyne acrita Chitwood, 1949
Meloidogyne arenaria (Neal, 1889) Chitwood, 1949
Meloidogyne chitwoodi Golden, O'Bannon, Santo & Finley, 1980
Meloidogyne cruciani García-Martinez, Taylor & Smart, 1982
Meloidogyne decalineata Whitehead, 1968
Meloidogyne hapla Chitwood, 1949
Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949
Meloidogyne javanica (Treub, 1885) Chitwood, 1949
Meloidogyne naasi Franklin, 1965
Meloidogyne ottersoni (Thorne, 1969) Franklin, 1971
Meloidogyne sp.

Family Criconematidae

Criconema duplicivestitum (Andrássy, 1963) Raski & Luc, 1985
Criconema sp.
Mesocriconema curvatum (Raski, 1952) Loof & De Grisse, 1989
Mesocriconema douceti (Siddiqi, 1986) Ebsary, 1991
Mesocriconema ornatum (Raski, 1958) Loof & De Grisse, 1989
Mesocriconema peruensiforme (De Grisse, 1967) Loof & De Grisse, 1989
Mesocriconema ritteri (Doucet, 1980) Loof & De Grisse, 1989
Mesocriconema sphaerocephala (Taylor, 1936) Loof & De Grisse, 1989
Mesocriconema talense (Chaves, 1983) Loof & De Grisse, 1989
Mesocriconema xenoplax (Raski, 1952) Loof & De Grisse, 1989
Mesocriconema sp.
Nothocriconema mutabile (Taylor, 1936) De Grisse & Loof, 1965
Nothocriconema sp.
Caloosia paradoxa (Luc, 1958) Brzeski, 1974
Hemicycliophora arenaria Raski, 1958
Hemicycliophora filicauda Doucet, 1982
Hemicycliophora fragilis Doucet, 1982
Hemicycliophora gracilis Thorne, 1955
Hemicycliophora penetrans Thorne, 1955
Hemicycliophora poranga Monteiro & Lordello, 1978
Hemicycliophora rara Doucet, 1983
Hemicycliophora rionegrensis Doucet, 1982
Hemicycliophora ripa Van den Berg, 1981
Hemicycliophora tenuistriata Doucet, 1982
Hemicycliophora thienemanni (Schneider, 1925) Loos, 1948
Hemicycliophora zuckermani Brzeski, 1963
Hemicycliophora sp.
Ogma alternatum (Doucet, 1986) Raski & Luc, 1987
Ogma comahuense Brugni & Chaves, 1994
Ogma multisquamatum (Kirjanova, 1948) Mehta & Raski, 1971

Family Tylenchulidae

Gracilacus colina Huang & Raski, 1986
Paratylenchus neoamblycephalus Geraert, 1965
Paratylenchus sp.
Tylenchulus semipenetrans Cobb, 1913

Family Allantonematidae

Metaparasitylenchus sp.